Integrating Wind Power into the Electric Power System



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Great Lakes Offshore Wind Gathering
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Key Integration Issues

- Costs (capital, energy, O&M)
- Variability Impacts (ancillary services costs)
- Energy (fuel displacement) and Capacity (serving demand growth) Contributions
- Environmental Considerations

Wind Energy Cost Trend

1979: 40 cents/kWh

2000:
4 - 6 cents/kWh
(no subsidy)

- Increased Turbine Size
- R&D Advances
- Manufacturing Improvements
- Operating Experience

NSP 107 MW Lake Benton wind farm
4 cents/kWh (unsubsidized)

2004:
3 - 5 cents/kWh
(no subsidy)

Natural Gas Situation

"Today's tight natural gas markets have been a long time in coming, and distant futures prices suggest that we are not apt to return to earlier periods of relative abundance and low prices anytime soon."

– Alan Greenspan, Federal Reserve Chairman,
Testimony at Senate hearing, July 10, 2003

Wellhead gas costs - 2002-2003: $3 - $5/MMBTU

Current prices and projections exceed $6/MMBTU

Cost Comparison

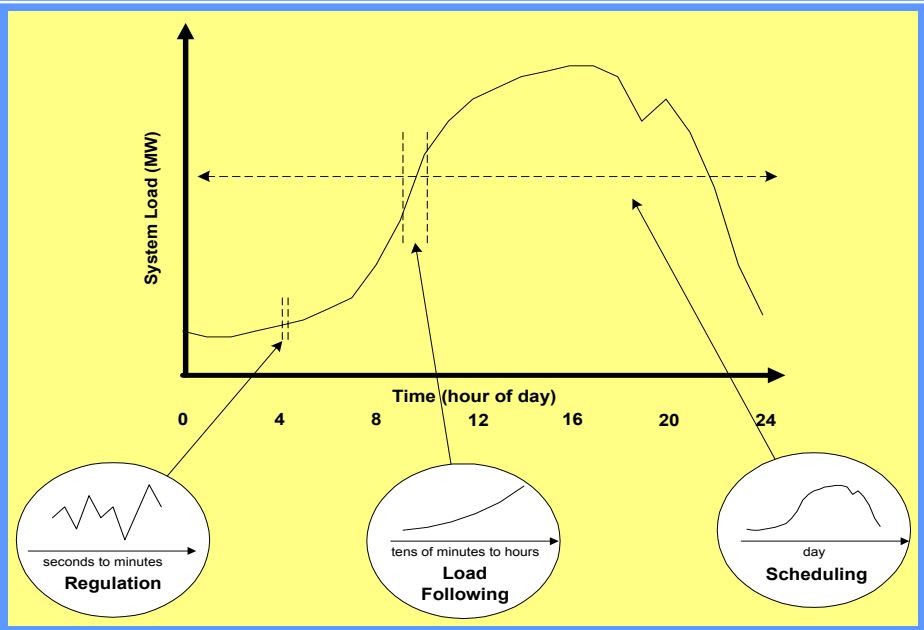
- Wind total capital cost: $1,300 - $1,400 kW today
- Wind energy cost: about 5¢/kWh (6¢ without PTC)
- Includes 0.5 to 1.0¢/kWh for O&M
- Wind energy costs are ***stable*** over plant lifetime

Natural-gas plant fuel cost (HR 7,000 - 10,000)

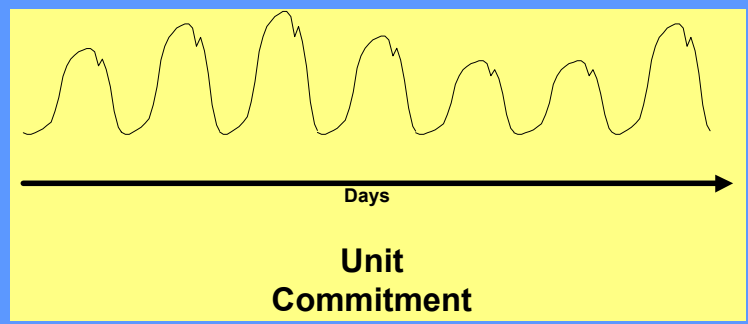
$/MMBTU:	2	4	5	6	8	gas cost
¢/kWh:	1.4 - 2	2.8 - 4	3.5 - 5	4.2 - 6	5.6 - 8	***fuel only***

- Wind-gas synergy: save gas when wind blows; burn gas to maintain system reliability during low winds

Wind Variability: Power-System Operation Impacts



- Regulation -- seconds to a few minutes -- similar to variations in customer demand
- Load-following -- tens of minutes to a few hours -- demand follows predictable patterns, wind less so



- Scheduling and commitment of generating units -- hours to several days -- wind forecasting capability?

Supply-demand balance maintained instantaneously.

Wind controlled by nature, not power-plant operators!

Wind Variability Can Increase Power System Operating Costs

- Committing unneeded generation
- Allocating extra load-following capability
- Allocating additional regulating capacity
- Increased cycling operation
- **These are reflected in *ancillary services* costs**

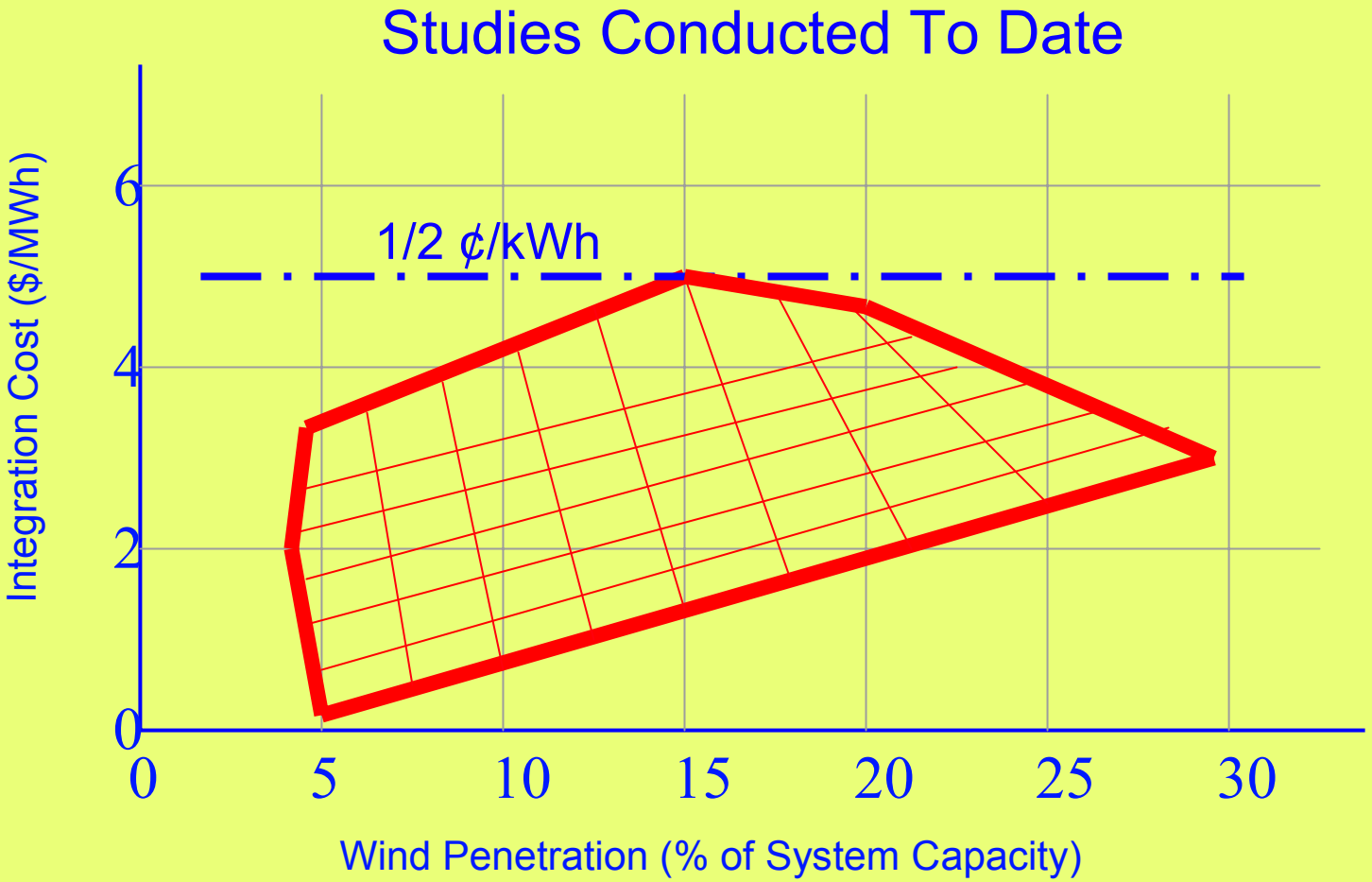
Incremental cost added by wind's variability?
Utility Wind Integration Group 2003 case study:
$1.85/MWh of wind energy (<10% of value)

System Operating Costs Impacts: Results from Recent Studies ($/MWh)

Study	Penetration (%)	Regulation	Load-Follow	Unit-Commit	Total Impact
UWIG/Xcel	3.5	0	0.41	1.44	1.85
Pacificorp	20	0	1.6	3.0	4.6
BPA/Hirst	7	0.19	0.28	1.40	1.87
We Energies	29	1.02	0.15	1.75	2.92
Xcel/MNDOC	15	0.23	0	4.37	4.60
Xcel/PSCO	15	0.20	0	4.77*	4.97

* includes $1.45 for new gas storage

Range of System Operating Cost Impacts



All results to date fall within the crosshatched area

GE Energy/NYISO/NYSERDA New York Wind Evaluation

- *Comprehensive study* of wind's impacts on transmission system planning, reliability and operations
- 3,300 MW of wind in system serving 34,000 MW of customer load *(10% wind penetration)*
- Energy prices based on *functioning commercial wholesale markets* -- day-ahead and hour-ahead
  - All previous studies based on operating costs only
- *Assumes wind is a price-taker*
  - Market (demand-supply balance) sets price; wind generators are paid the market price

GE Energy/NYISO/NYSERDA New York Wind Evaluation

- *Overall Conclusion: NY State power system can reliably accommodate at least 10% wind (3,300 MW)*
  - Minor adjustments to planning, operation and reliability practices
- Total NY system (less wind) variable operating costs (fuel, plant startup costs, etc.) reduced by $350 M
- State-of-the-art wind forecasting contributed $125 M of this reduction (about 80% of perfect-forecast value)
- Electricity costs reduced statewide
- System transient stability improved

GE Energy/NYISO/NYSERDA New York Wind Evaluation

❖ *Load payment reductions (savings to energy consumers):*	$305 M or about 0.18¢/kWh
❖ *Energy displacement:*	65% natural gas, 15% coal, 10% oil, 10% imports
❖ *Emissions reductions:*	NOx -- 6,400 tons (10%);
	SOx -- 12,000 tons (5%)
❖ *Wind revenue:*	$315 M (about 3.5¢/kWh)

Wind's Contributions to Electric Power

Energy: displacement of fossil fuels

- In most cases, this is the primary motivation. Previously existing power plants run less, but continue to be available to ensure system reliability.
- Contrary to common lore, addition of a wind plant requires NO new conventional backup generation to maintain system reliability.
- In many cases, natural gas is saved, reducing total system operating costs. In all cases, overall emissions are reduced.

Wind's Contributions to Electric Power

Capacity: meeting new load growth

- Because of its variability, wind is less effective in this respect than conventional generation. Winds may be low during peak electricity demand periods.
- Nonetheless, addition of a wind plant will allow some new load to be served. The amount depends on many factors. Examples:

New York	about 10%
Long Island	about 40%
Minnesota	about 25%

- With experience and over time, operating strategies and generation mix will evolve so that combinations of wind and other plants like hydro and natural gas will serve new load reliably.

Environmental Benefits of Wind

- *No emissions* of any kind during operation
  - No SOx, NOx, particulates or mercury
  - No contributions to regional haze
  - Hedge against environmental regulations
  - No greenhouse gases
- *No toxic wastes or health impacts*
  - Nuclear waste transport and storage unresolved
  - Respiratory diseases of growing concern
- *No water consumption or use during operation*
  - Water availability a looming crisis in the Western US

Environmental Benefits of Wind

- *Global climate change concerns can no longer be ignored by any legitimate political entity*
  - Most environmental scientists view this as by far the most serious environmental issue facing society
  - Unavoidable evidence mounting
  - Very few doubters remain
- *Not many arrows in the quiver to address this concern*
- *We need them all*
- *Wind energy is one of them*

Paul Anderson, CEO of Duke Energy (Southeastern Utility, Coal/Nuclear)

Lobbying for tax on carbon dioxide emissions

"Personally, I feel the time has come to act - to take steps as a nation to reduce the carbon intensity of our economy. And it's going to take all of us to do it."

– Paul Anderson, quoted in AP press release, published April 7, 2005

Environmental Tradeoffs

We need to evaluate environmental impacts on a relative basis.

No energy-generation approach is without impacts.

The choice is wind vs. *something* -- not wind vs. *nothing.*

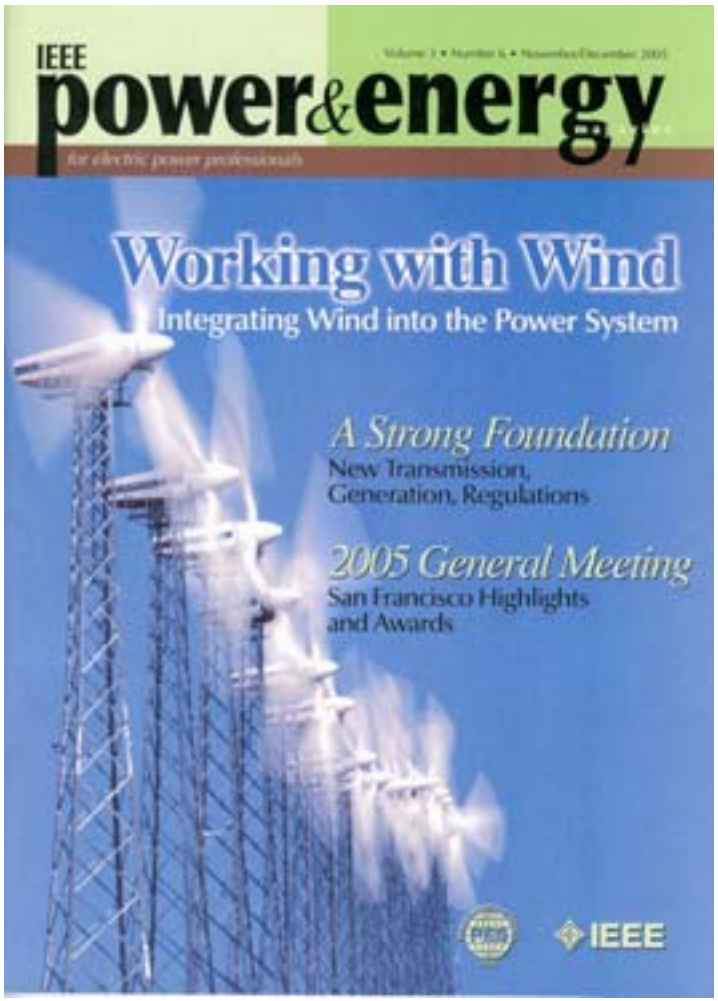
How Will Cost Comparisons Evolve?

- Wind is competitive with conventional energy today in many cases
- Wind costs likely to drop if market stability improves -- stop-start syndrome has raised costs
- Wind integration costs: about 0.5¢/kWh or less
- Natural-gas price-risk hedge value of wind: Lawrence Berkeley Lab estimate: about 0.5¢/kWh
- Carbon-emissions penalty would improve wind's competitiveness
- Technology advancement benefits will continue

Wind's integration costs are likely to be more than offset by other factors yet to be applied.

UWIG
Utility Wind Integration Group

Accelerating the Integration of Wind Generation into Utility Power Systems



- IEEE Power Engineering Society Magazine, November/December 2005
- Utility Wind Integration Group (UWIG): Operating Impacts and Integration Studies User Group
- www.uwig.org